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Electro-Mechanical Developments for the HPGe Detectors of the N3G Experiment

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The N3G Experiment

The **N3G** experiment (**Next Generation Germanium Gamma Detectors**) is aimed at developing the Pulsed Laser Melting (PLM) technology to realize **complex coaxial HPGe** (Hyper-Pure Germanium) **segmented detectors** and testing their potentiality to face the challenges of future nuclear science high-flux and high-damage experiments. To achieve these goals, the collaboration needs also to design the front-end electronics to read the detectors' signals and the mechanical systems to support them.

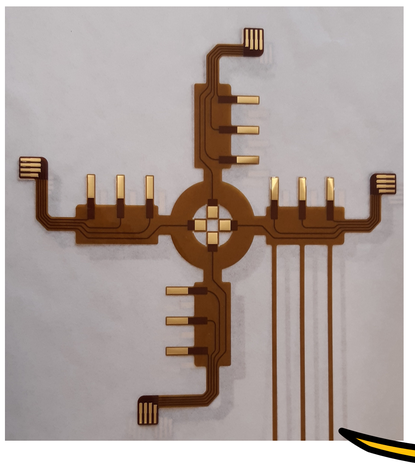
Front-End Electronics (FEE)

A new dedicated front-end electronics was developed. It is based on an ASIC realized in AMS C35B4C3 (350 nm) technology. The CSP (Charge Sensitive Pre-amplifier) was designed in two different versions, hybrid discrete-integrated and fully integrated. It is characterized by 6 mW power consumption and 8 MeV dynamic range, that can be extended up to 40 MeV thanks to an innovative fast-reset system [2].

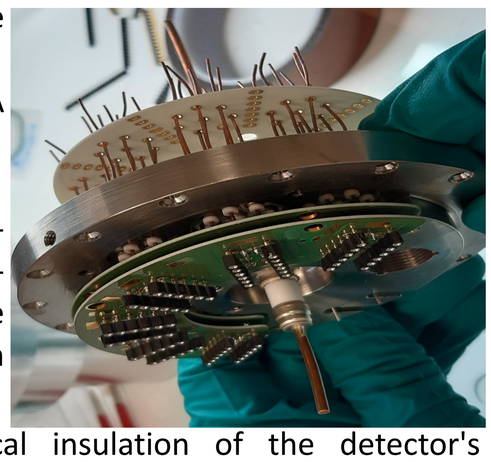
Detector Description

Thanks to the innovative **Pulsed Laser Melting technique** [1], it is possible to obtain thin n+ doped layers (100 nm - 300 nm) which can be divided in segments. In such a way HPGe detectors with opposite polarity with respect to those of the state-of the-art can be realized. **Collecting electrons** on the external electrodes **improves the performances** of these devices, because electrons are much less subject to trapping induced by neutron damage than holes.

Electrical Connections

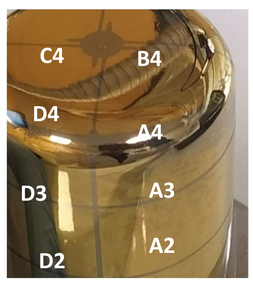


The external electrodes of the detector are connected to the read-out electronic chain through a two-steps system. It consists of a **flexible PCB, realized on a kapton substrate,** connected to a second set of rigid PCBs. These rigid boards carry the signals to the preamplifiers housed outside the closing flange. Flexible PCBs have been successfully used in the framework of GERDA experiment.



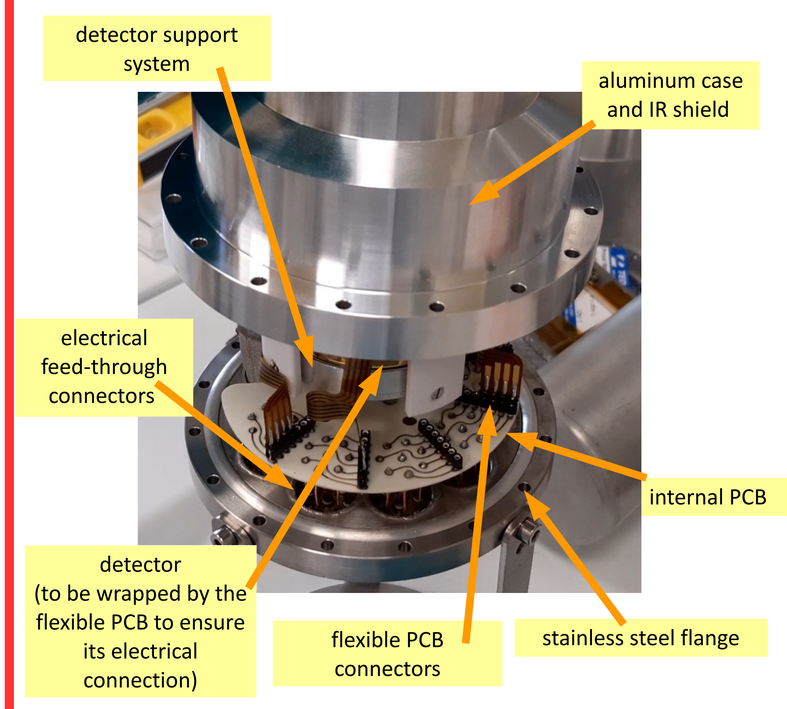
The electrical connections were tested in measuring the electrical insulation of the detector's electrodes, whose resistances, with respect to the adjacent ones, are greater than 100 MΩ. These measurements were performed at liquid-nitrogen temperature.

GΩ	C1	C3	D2	D4
up	0.4	20	1.4	/
down	/	0.6	7.5	3.0
right	6.0	7.7	5.3	31.3
left	4.3	25.0	0.1	12.8



HPGe Detector

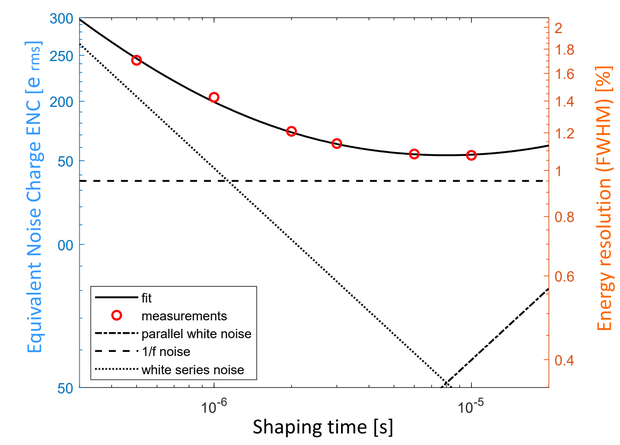
Mechanical Case



The N3G detector is placed with its electrical connections inside an aluminum **vacuum chamber** closed at the bottom by a **specifically designed flange**. The flange is equipped with six feed-through connectors for the signals, a high-voltage rod and a vacuum inlet. The chamber has been designed for compatibility with the cryostats available at LNL. For the preliminary tests a dummy detector was designed and 3D printed. Germanium detectors are typically encapsulated inside aluminum cases closed by steel flanges, as reported by Mirion Technologies [3].

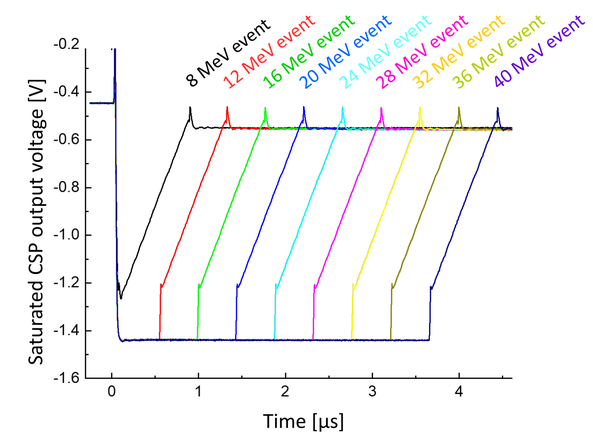
FEE Characterization

The circuit Equivalent Noise Charge (ENC) and energy resolution were measured connecting the CSP to a Quasi-Gaussian Shaping Amplifier. The best resolution (FWHM) of **1.08 keV @ 1 MeV** was obtained with 10 µs shaping time.

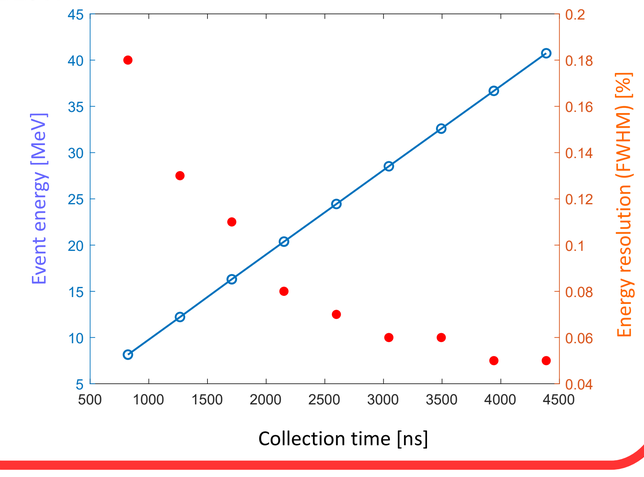


To improve the previous results, a second low-noise and low-power consumption CSP was designed. The simulated resolution (FWHM) @ 1 MeV, with 10 µs shaping time and 15 pF detector capacitance, is 0.77 keV FWHM.

The innovative fast-reset circuit that equips the CSP allows to **retrieve the energy information on the events that bring the pre-amplifier into saturation.** This is possible because the time required to collect the charge at the CSP input node is proportional to its amount and, consequently, to the energy released inside the detector by the interaction.



The linearity and resolution measurements are shown. **For events of energy greater than 15 MeV the resolution (FWHM) is better than 0.11%.**



References

[1] CARRARO, Chiara, et al. N-type heavy doping with ultralow resistivity in Ge by Sb deposition and pulsed laser melting. Applied Surface Science, 2020, 509: 145229.

[2] CAPRA, Stefano; SECCI, Giacomo; PULLIA, Alberto. An Innovative Analog Circuit to Retrieve Energy Information From Signals of Deeply Saturated Preamplifiers Connected to Semiconductor Detectors. IEEE Transactions on Nuclear Science, 2022, 69.7: 1757-1764.

[3]https://www.mirion.com/products/technologies/spectroscopy-scientific-analysis